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STAT730

Advanced Research Methods

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STAT730

Advanced Research Methods

Lecture-Wise Study Handout
Virtual University of Pakistan

12 lectures • prepared for exam study

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About This Course

Advanced Research Methods trains MS Statistics students to design, execute and report original research. It integrates the full research cycle — from identifying a problem and reviewing literature, through design, sampling, measurement and analysis, to writing and defending the thesis — with the statistical rigour the degree demands.

Each lecture covers one research stage with principles, techniques, worked reasoning and exam pointers, including the statistical methods (estimation, testing, regression, multivariate) as research tools rather than ends in themselves.

Lecture 1: Research and the Scientific Method

Learning Objectives

- Define research
- Choose paradigms and types

Research is systematic, controlled, empirical investigation aimed at discovering or revising knowledge. The scientific method — observe, hypothesize, predict, test, revise — distinguishes research from casual inquiry: it is replicable, self-correcting and evidence-bound. Statistics is the method's quantitative language: design, estimation and inference.

Research paradigms frame the work. Positivism seeks objective measurement and general laws (the natural home of statistical research); interpretivism seeks understanding of meaning (qualitative inquiry); pragmatism mixes methods by problem. MS Statistics theses are typically positivist and quantitative, but knowing the paradigms defends methodological choices in the viva.

Research types: basic (theory-building) vs applied (problem-solving); exploratory, descriptive, explanatory; cross-sectional vs longitudinal. A thesis must declare its type — it determines design, sampling and analysis. Very important exam theme: align paradigm, type, design and analysis into one coherent chain.

Key Definitions

Research is defined as systematic, controlled, empirical investigation aimed at discovering or revising knowledge

Key Points — very important for exams

Research = systematic empirical inquiry; scientific method: observe → hypothesize → test → revise.

Paradigms: positivism (measurement), interpretivism (meaning), pragmatism (mixed).

Declare research type — it chains to design, sampling and analysis.

Review Questions

- ? How does research differ from casual inquiry?
- ? Why must paradigm, type and design align?

Section Summary

Research is disciplined inquiry; paradigms and types frame every later choice.

Exam Pointers

- Define research and contrast paradigms; classify research types.

Lecture 2: Identifying the Research Problem

Learning Objectives

- Formulate research problems
- Write questions and hypotheses

A research problem is a knowledge gap worth filling: it states what is unknown, why it matters, and what the study will do about it. Sources: literature gaps, contradictory findings, practical problems, theory extensions, supervisor expertise. The problem must be researchable — answerable with data — significant, and feasible within time and resources.

From problem to questions to objectives to hypotheses: research questions ask (does X affect Y?), objectives promise (to estimate the effect of X on Y), hypotheses assert testable claims (H_0 : no effect). In statistics, hypotheses are stated about parameters — $H_0: \beta_1 = 0$ — linking the research design directly to the inference machinery.

The FINER criteria judge questions: Feasible, Interesting, Novel, Ethical, Relevant. A problem failing feasibility — no data access, impossible sample — fails outright. Examiners ask students to convert a vague topic into FINER questions: practise this transformation.

Key Definitions

FINER is defined as criteria for good research questions: Feasible, Interesting, Novel, Ethical, Relevant

Key Points — very important for exams

Problem = knowledge gap: unknown, important, researchable, feasible.

Chain: problem → questions → objectives → statistical hypotheses (about parameters).

FINER judges questions; feasibility is the binding constraint.

Review Questions

- ? What makes a problem researchable?
- ? State H_0/H_a for: does training affect productivity?

Section Summary

Good research starts with a FINER gap, sharpened into testable hypotheses.

Exam Pointers

- Convert a topic into a research problem, questions, objectives and hypotheses.

Lecture 3: Literature Review and Meta-Analysis

Learning Objectives

- Conduct literature reviews
- Understand meta-analysis

The literature review maps what is known: it synthesizes — not lists — prior studies, identifies gaps and contradictions, and positions the thesis's contribution. Sources: peer-reviewed journals (top priority), books, conference proceedings, theses, and grey literature — searched via Google Scholar, Scopus/Web of Science, with citation chaining (backward and forward).

Critical appraisal judges each study: design, sample, measures, analysis, and whether conclusions follow. Organize thematically or methodologically — never as an annotated bibliography. The review must end by deriving the study's hypotheses or model from the synthesis: this is the literature, therefore this gap, therefore this study.

Systematic reviews and meta-analysis are advanced forms: pre-registered protocols, exhaustive search, quality appraisal, and quantitative synthesis (pooled effect sizes, forest plots, heterogeneity I^2 , publication-bias checks). A meta-analysis chapter can itself be a thesis contribution.

Key Definitions

Meta-analysis is defined as quantitative synthesis pooling effect sizes across studies, with heterogeneity and bias checks

Key Points — very important for exams

Review synthesizes (not lists): search systematically, appraise critically, organize thematically, derive the gap.

Sources: journals first; Scholar/Scopus; citation chaining both directions.

Meta-analysis: protocol → search → appraise → pool effects → check heterogeneity and publication bias.

Review Questions

- ? What distinguishes synthesis from an annotated bibliography?
- ? What is I^2 in meta-analysis?

Section Summary

Map the knowledge, find the gap, and let the literature earn your hypotheses.

Exam Pointers

- Describe the literature review process and meta-analysis steps.

Lecture 4: Theoretical Framework and Variables

Learning Objectives

- Build conceptual frameworks
- Classify variables

The theoretical/conceptual framework explains why variables relate: theory provides the mechanism (e.g. human capital theory linking education to earnings), the conceptual framework diagrams the study's variables and hypothesized paths. Without it, analysis is fishing; with it, hypotheses are deductions.

Variables: independent (cause), dependent (effect), mediating (mechanism: $X \rightarrow M \rightarrow Y$), moderating (condition: X's effect depends on Z), control (held constant). Operational definitions translate concepts into measurable variables — education becomes years of schooling; performance becomes sales per employee.

The framework chapter ends with the research model diagram and formal hypotheses. In statistics theses this is often a regression/SEM specification — the bridge from theory to estimation. Very important: every hypothesis tested later must appear here first.

Key Definitions

Mediator vs moderator is defined as a variable transmitting an effect ($X \rightarrow M \rightarrow Y$) versus one conditioning it

Key Points — very important for exams

Theory supplies mechanisms; the framework diagrams variables and paths — hypotheses are deductions.

Variable types: independent, dependent, mediator, moderator, control.

Operationalize every concept; every tested hypothesis appears here first.

Review Questions

? Distinguish mediator from moderator with an example.

? Operationalize job satisfaction for a survey.

Section Summary

Theory → framework → variables → hypotheses: the deductive spine of the thesis.

Exam Pointers

→ Build a conceptual framework with variable types and operational definitions.

Lecture 5: Research Designs

Learning Objectives

- Choose research designs
- Manage validity threats

Research design is the blueprint. Experimental designs (randomized controlled trials) maximize internal validity through randomization, control groups and manipulation — the gold standard for causality.

Quasi-experiments (non-equivalent groups, time series, regression discontinuity) approximate it where randomization is impossible.

Non-experimental designs: cross-sectional surveys (one time point — descriptive and correlational), longitudinal/panel (repeated measures — change and dynamics), case studies (deep single-unit inquiry), and causal-comparative ex post facto. Choose by question: causality → experiments; prevalence/association → surveys; process → longitudinal/case.

Validity threats: history, maturation, testing, instrumentation, selection, mortality (attrition), and their interactions. Design is threat management: randomization, pretests, control groups and blinding each neutralize specific threats. The design chapter must name the threats and the countermeasures — examiners check this explicitly.

Key Definitions

Internal validity is defined as the degree to which a design supports causal inference, threatened by history, maturation, selection, etc.

Key Points — very important for exams

Experiments (RCTs): gold standard via randomization; quasi-experiments approximate it.

Surveys: prevalence/association; longitudinal: change; case studies: depth.

Design = threat management: name each validity threat and its countermeasure.

Review Questions

? Why is randomization powerful?

? Which design for: does training raise productivity over two years?

Section Summary

Match design to question, then defend it threat by threat.

Exam Pointers

→ Compare experimental, quasi-experimental and survey designs with validity threats.

Lecture 6: Sampling: Methods and Sample Size

Learning Objectives

- Design sampling plans
- Determine sample size

Sampling represents the population. Probability sampling — simple random, systematic, stratified (by subgroups), cluster (by groups), multistage — gives every unit a known selection chance, enabling unbiased estimation and inference. Stratify when subgroups matter; cluster when populations are geographically dispersed.

Non-probability sampling — convenience, purposive, quota, snowball — is cheaper and sometimes the only option (hidden populations), but results don't generalize statistically; justify it explicitly. Sampling frame problems (incomplete lists, non-response) are the practical enemy — report response rates and weight adjustments.

Sample size: power analysis sets n from effect size, alpha and desired power (0.80 standard); rules of thumb (10–20 observations per regression predictor) are fallback. For surveys, the margin-of-error formula $n = z^2p(1-p)/e^2$ sizes proportions. Underpowered studies are unethical — they waste respondents' time on inconclusive results.

Key Definitions

Power analysis is defined as the sample size needed to detect an effect of given size with specified alpha and power

Key Points — very important for exams

Probability sampling (random, stratified, cluster, multistage) enables inference; non-probability needs justification.

Stratify for subgroups, cluster for geography; fight frame and non-response bias.

Size by power analysis (power 0.80) or margin-of-error formula; underpowered = unethical.

Review Questions

- ? When is cluster sampling preferred to stratified?
- ? What does power 0.80 mean?

Section Summary

Sample so results generalize — probabilistically when possible, and always with adequate power.

Exam Pointers

→ Compare sampling methods; compute survey sample size; explain power analysis.

Lecture 7: Measurement, Scales and Questionnaires

Learning Objectives

- Choose measurement scales
- Build reliable, valid instruments

Measurement assigns numbers to concepts. Scales: nominal (categories), ordinal (ranked), interval (equal gaps), ratio (true zero) — the level determines permissible statistics (means need interval+; chi-square suits nominal). Likert scales (agree–disagree items) are the survey workhorse; treat sums as approximately interval with care.

Reliability is consistency: test–retest, split-half, and Cronbach's alpha (≥ 0.70 acceptable) for multi-item scales. Validity is accuracy: content (expert coverage), criterion (correlation with gold standards), construct (convergent/discriminant evidence, factor analysis). A measure can be reliable but invalid — consistently wrong.

Questionnaire design: clear, single-idea items; no leading or double-barrelled questions; sensible ordering (general → specific, sensitive items last); pilot testing on 20–30 respondents. Measurement error attenuates relationships — the statistics lectures' warning, now a design imperative.

Key Definitions

Cronbach's alpha is defined as internal consistency of a scale, acceptable at 0.70 and above

Key Points — very important for exams

Scales: nominal, ordinal, interval, ratio — level governs statistics.

Reliability (consistency: $\alpha \geq 0.70$) vs validity (accuracy: content, criterion, construct).

Questionnaire craft: clear single-idea items, no leading/double-barrelled, pilot test.

Review Questions

- ? Why can a measure be reliable but invalid?
- ? What is a double-barrelled question? Give an example.

Section Summary

Measure at the right scale, consistently and accurately — or all analysis is built on sand.

Exam Pointers

- Explain scale levels, reliability, validity and questionnaire principles.

Lecture 8: Data Collection, Processing and Ethics

Learning Objectives

- Plan data collection
- Handle data ethically

Data collection must be planned and ethical: permissions, trained enumerators, standardized protocols, and field monitoring. Primary data (collected for the study) fit the question exactly but cost more; secondary data (existing datasets — PSLM, Labour Force Survey, firm records) are cheap and large but may mismatch concepts.

Data processing: coding, entry validation (double entry for critical data), cleaning (range checks, logic checks, duplicates), and missing-data handling — MCAR/MAR/MNAR mechanisms; multiple imputation for MAR, sensitivity analysis otherwise. Document every decision in a data appendix.

Research ethics: institutional review, informed consent, voluntary participation, confidentiality/anonymity, no harm, honest reporting. Statistical ethics add: no p-hacking, no HARKing (hypothesizing after results known), pre-registration of analysis plans, and reporting null results. Fabrication is career-ending misconduct.

Key Definitions

HARKing is defined as presenting post-hoc findings as if hypothesized beforehand — a form of research misconduct

Key Points — very important for exams

Primary fits, secondary is cheap — choose deliberately; plan collection rigorously.

Clean systematically: validation, range/logic checks, principled missing-data handling.

Ethics: consent, confidentiality, no harm — plus no p-hacking, no HARKing, pre-register.

Review Questions

? When is multiple imputation appropriate?

? Why is HARKing misconduct?

Section Summary

Collect cleanly, process transparently, and let ethics govern every number.

Exam Pointers

→ Describe data processing and research ethics including p-hacking and HARKing.

Lecture 9: Descriptive and Inferential Analysis

Learning Objectives

- Summarize data
- Conduct inference properly

Descriptive statistics summarize before modelling: distributions (histograms, boxplots), centres (mean/median/mode), spread (SD, IQR), and bivariate views (scatterplots, cross-tabs, correlations). Exploratory data analysis often reveals the story — and the data problems — before any test is run.

Estimation: point estimates with confidence intervals — the interval, not just the point, is the finding. Hypothesis testing: state H_0/H_a , choose alpha, compute the test statistic and p-value, and interpret correctly — p is $P(\text{data}|H_0)$, not $P(H_0|\text{data})$. Report effect sizes alongside significance; a significant trivial effect misleads.

Choose tests by variable types: t-tests/ANOVA for group means, chi-square for associations, correlation/regression for relationships, non-parametrics (Mann–Whitney, Kruskal–Wallis) when assumptions fail. The analysis plan, written before seeing data, prevents fishing.

Key Definitions

p-value is defined as the correct interpretation: the probability of data as extreme, assuming H_0 true

Key Points — very important for exams

Explore first: distributions, EDA plots — find stories and problems early.

Estimate with intervals; test with correct p-value interpretation; report effect sizes.

Match test to variable types; pre-plan analyses to prevent fishing.

Review Questions

? What is the most common misinterpretation of p-values?

? Which test compares three group means?

Section Summary

Describe honestly, estimate with intervals, test with understanding.

Exam Pointers

→ Outline descriptive and inferential analysis with correct p-value interpretation.

Lecture 10: Regression and Multivariate Methods in Research

Learning Objectives

- Apply regression in theses
- Choose multivariate methods

Regression is the thesis workhorse: multiple regression estimates ceteris-paribus effects; logistic regression handles binary outcomes (odds ratios); panel methods (fixed/random effects) exploit longitudinal data; the full diagnostics battery (from STA5204) must be reported. Present tables with coefficients, standard errors, p-values and model fit — and interpret magnitudes, not just stars.

Multivariate extensions: factor analysis/PCA reduce dimensionality and validate constructs; cluster analysis segments; structural equation modelling tests whole causal systems with latent variables; MANOVA handles multiple outcomes. Match the method to the framework's hypotheses — complexity must be justified, not displayed.

Robustness checks separate credible theses: alternative specifications, subsamples, different estimators. If the finding survives, it is a finding; if not, report the fragility. Examiners probe exactly this: what did you do to try to break your result?

Key Definitions

Structural equation modelling (SEM) is defined as simultaneous estimation of systems of equations with latent variables

Key Points — very important for exams

Regression workhorse: multiple, logistic, panel — full diagnostics, interpret magnitudes.

Multivariate: factor analysis, clustering, SEM, MANOVA — justify complexity.

Robustness: alternative specs and samples; report fragility honestly.

Review Questions

- ? What belongs in a regression results table?
- ? Why run robustness checks?

Section Summary

Model the framework's hypotheses, diagnose thoroughly, and stress-test every finding.

Exam Pointers

→ Describe regression reporting and multivariate methods with robustness checks.

Lecture 11: Qualitative and Mixed Methods

Learning Objectives

- Understand qualitative inquiry
- Design mixed-method studies

Qualitative methods complement statistics: in-depth interviews (lived experience), focus groups (group dynamics), case studies (holistic depth), ethnography (immersion). Sampling is purposive (information-rich cases); sample size follows saturation — when new interviews add nothing new.

Analysis: thematic coding (familiarize → code → theme → review → define), supported by software (NVivo) or careful manual work; trustworthiness via credibility (member checks), transferability (thick description), dependability (audit trails), confirmability (reflexivity). These parallel validity/reliability in quantitative language — useful viva terminology.

Mixed methods integrate both: sequential explanatory (survey then interviews explaining surprises), sequential exploratory (interviews then survey testing themes), convergent (parallel, merged). The design must justify mixing — each method answering questions the other cannot.

Key Definitions

Saturation is defined as the point in qualitative sampling when new data add no new themes

Key Points — very important for exams

Interviews, focus groups, cases, ethnography — purposive sampling to saturation.

Thematic analysis; trustworthiness: credibility, transferability, dependability, confirmability.

Mixed methods: explanatory, exploratory, convergent — justify why both are needed.

Review Questions

- ? How does saturation determine sample size?
- ? When is a sequential explanatory design appropriate?

Section Summary

Depth complements breadth — mix methods deliberately, with each earning its place.

Exam Pointers

→ Describe qualitative methods, trustworthiness criteria and mixed-method designs.

Lecture 12: Thesis Writing and the Viva

Learning Objectives

- Structure a thesis
- Prepare for the viva

The thesis has a standard architecture: title page, abstract (problem, method, key findings — one page), introduction (problem, questions, significance), literature review, methodology (design, sampling, measures, analysis — replicable detail), results (tables/figures, no interpretation), discussion (interpret, compare with literature, implications), conclusion, references (APA), appendices (instruments, extra tables).

Academic writing: precise, concise, hedged appropriately (the data suggest, not prove); tables and figures self-contained with numbered captions; citations every claim that isn't yours. The discussion — not the results — is where the thesis earns its degree: interpret findings, confront contradictions, state limitations honestly, propose future research.

The viva defends it: anticipate questions on every choice (why this design? this sample? this estimator?), prepare a 15-minute summary, and treat examiners as critical allies. Revisions after the viva are normal — a thesis is finished when the examiners say so.

Key Definitions

Thesis architecture is defined as the standard thesis structure from abstract through discussion to references

Key Points — very important for exams

Architecture: abstract → intro → literature → methodology → results → discussion → references.

Discussion earns the degree: interpret, compare, admit limits, propose next steps.

Viva: defend every choice; revisions are normal; precision and hedging throughout.

Review Questions

- ? What goes in results vs discussion?
- ? How should limitations be handled?

Section Summary

Write replicably, discuss courageously, defend calmly — the thesis as scholarly argument.

Exam Pointers

- Outline thesis structure and describe what the discussion chapter must do.

Glossary of Key Terms

Research — systematic, controlled, empirical investigation aimed at discovering or revising knowledge

FINER — criteria for good research questions: Feasible, Interesting, Novel, Ethical, Relevant

Meta-analysis — quantitative synthesis pooling effect sizes across studies, with heterogeneity and bias checks

Mediator vs moderator — a variable transmitting an effect ($X \rightarrow M \rightarrow Y$) versus one conditioning it

Internal validity — the degree to which a design supports causal inference, threatened by history, maturation, selection, etc.

Power analysis — the sample size needed to detect an effect of given size with specified alpha and power

Cronbach's alpha — internal consistency of a scale, acceptable at 0.70 and above

HARKing — presenting post-hoc findings as if hypothesized beforehand — a form of research misconduct

p-value — the correct interpretation: the probability of data as extreme, assuming H_0 true

Structural equation modelling (SEM) — simultaneous estimation of systems of equations with latent variables

Saturation — the point in qualitative sampling when new data add no new themes

Thesis architecture — the standard thesis structure from abstract through discussion to references